



**INTERNATIONAL JOURNAL OF  
PHARMACEUTICAL SCIENCES**  
[ISSN: 0975-4725; CODEN(USA): IJPS00]  
Journal Homepage: <https://www.ijpsjournal.com>



## Research Paper

# Design, Optimization, and Physicochemical Characterization of a Synergistic Octa-Ingredient Poly-Herbal Dermaceutical Scrub utilizing a Xanthan-Caffeine Matrix

**Brijesh Singh Negi\*, Pinky Bisht**

*Department of pharmaceuticals, Bhagwant Global University, Kotdwar, Uttarakhand.*

## ARTICLE INFO

Published: 06 Oct 2026

### Keywords:

Poly-herbal scrub, Coffea arabica, Xanthan Gum, Dermaceuticals, Rheology, Green Cosmetics.

### DOI:

10.5281/zenodo.23185828

## ABSTRACT

**Background:** The cosmetic industry is undergoing a transition from synthetic exfoliants to biodegradable alternatives due to the environmental toxicity of microplastics. There is an increasing clinical demand for multi-functional dermaceuticals that provide simultaneous exfoliation and antimicrobial protection. **Objective:** The present study aims to formulate and evaluate a stable, octa-ingredient poly-herbal face scrub incorporating Coffea arabica, Azadirachta indica, Santalum album, and Melaleuca alternifolia in a stabilized Xanthan-Glycerin gel matrix. **Methodology:** An optimized Cold-Process Incorporation method was utilized. Xanthan gum (1.5% w/w) was employed as a primary rheology modifier. The formulation was subjected to rigorous physicochemical characterization, including pH determination, spreadability, washability, and microbial limit testing (MLT) using Methyl Paraben as a standardized preservative. **Results:** The optimized batch (F2) exhibited a skin-compatible pH of  $5.9 \pm 0.12$  and excellent spreadability ( $14.22 \pm 0.45$  g·cm/sec). Centrifugation studies at 3000 RPM confirmed the physical stability of the suspended herbal particulates. The preservative efficacy test revealed a total aerobic count of  $<100$  CFU/g, complying with IP 2022 standards. **Conclusion:** The developed poly-herbal scrub offers a sustainable, non-toxic, and pharmacologically active alternative to synthetic preparations, demonstrating significant potential for the management of acne-prone and dull skin.

## INTRODUCTION

The human integumentary system is constantly exposed to environmental pollutants, microbial pathogens, and UV radiation, leading to the

accumulation of dead corneocytes and sebum. Mechanical exfoliation, the process of physically removing the stratum corneum, is essential for

**\*Corresponding Author:** Brijesh Singh Negi

**Address:** Department of pharmaceuticals, Bhagwant Global University, Kotdwar, Uttarakhand.

**Email** ✉: [negibrijesh10@gmail.com](mailto:negibrijesh10@gmail.com)

**Relevant conflicts of interest/financial disclosures:** The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

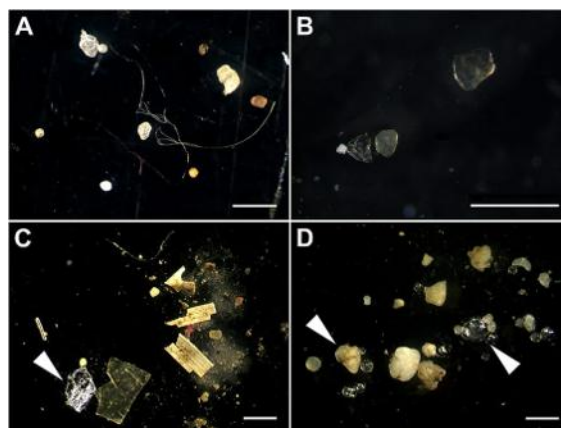


maintaining skin health and stimulating micro-circulation.

### 1.1 The Environmental Rationale

For decades, the cosmetic industry utilized polyethylene and polypropylene microbeads as primary exfoliants. However, these non-biodegradable microplastics have been identified

as significant aquatic pollutants. Consequently, international regulatory bodies have mandated a shift toward biodegradable alternatives. *Coffea arabica* (Coffee) grounds serve as an ideal candidate due to their dual action: providing controlled mechanical abrasion and releasing caffeine, a potent vasodilator and antioxidant. [12][14]



**Fig 1: Comparative Microscopic Morphology of Exfoliating Agents. (Left: Synthetic Polyethylene microbeads showing uniform but non-biodegradable structure; Right: Natural *Coffea arabica* particulates showing porous, biodegradable organic matrix suitable for sustainable dermaceuticals).**

“As illustrated in **Fig 1**, the irregular and porous surface of natural coffee grounds provides a superior mechanical advantage for cell desquamation compared to the smooth, environmentally persistent synthetic microbeads.”

### 1.2 The Octa-Ingredient Synergism

Modern pharmacotherapy emphasizes synergy—the interaction of multiple bio-actives to enhance efficacy while minimizing side effects. This formulation integrates eight distinct components to address complex skin pathologies: [6][3][8][9][10][11]

**Exfoliation & Stimulation:** Coffee Grounds (*Coffea arabica*).

**Antimicrobial Defense:** Neem (*Azadirachta indica*) and Tea Tree Oil (*Melaleuca alternifolia*).

**Dermal Healing:** Aloe Vera (*Aloe barbadensis*) and Turmeric (*Curcuma longa*).

**Skin Brightening:** Sandalwood (*Santalum album*).

**Moisture Retention:** Glycerin.

**Structural Stability:** Xanthan Gum.

### 1.3 Rheological Significance in Topical Systems

The formulation of a particulate-heavy scrub poses a significant pharmaceutical challenge: sedimentation. To ensure a homogenous distribution of herbal powders, a high-yield-value rheology modifier is required. Xanthan gum, a microbial exopolysaccharide, was selected for its unique pseudoplastic flow properties. It ensures that the high-density particulates remain suspended during storage while facilitating ease of application under shear stress.

## 1.4 Preservation Strategy

Given the high-water activity and nutrient-rich organic profile of herbal extracts, microbial stability is a primary concern. The inclusion of Methyl Paraben ensures protection against fungal and bacterial spoilage, thereby maintaining the therapeutic integrity of the dermatological product throughout its shelf-life.

## 2. MATERIALS AND METHODS

### 2.1 Procurement and Authentication of Ingredients

The herbal raw materials were procured from local standardized herbal suppliers and authenticated at the Department of Pharmacognosy, [Bhagwant Global University]. *Coffea arabica* seeds were roasted and ground to a specific particle size of 400–600 µm. Pure *Aloe barbadensis* leaf gel was extracted and filtered. Pharmaceutical-grade excipients, including Xanthan Gum (High

Viscosity Grade), Glycerine (IP Grade), and Methyl Paraben (LR Grade). Distilled water was used throughout the study for the preparation of the aqueous phase.

### 2.2 Equipment and Apparatus

The formulation was developed using a high-shear mechanical stirrer. Physicochemical evaluations were performed using a Digital pH Meter, Brookfield Viscometer (DV-E model), and a standardized Spreadability Apparatus.

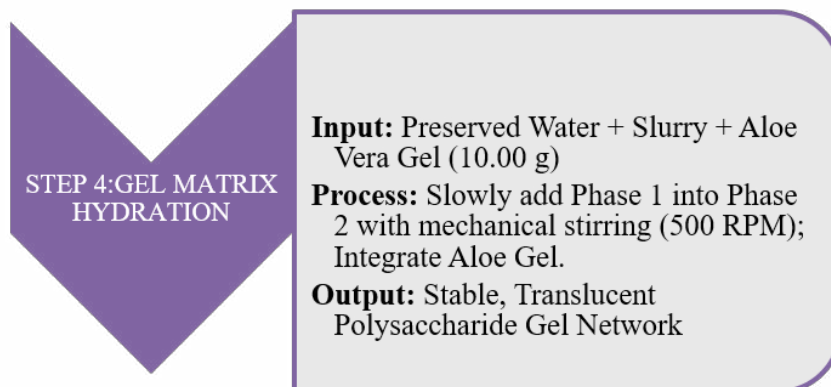
### 2.3 Formulation Design and Optimization

To achieve an ideal consistency and suspension stability, three pilot batches (F1, F2, and F3) were prepared with varying concentrations of Xanthan Gum (0.5%, 1.5%, and 2.5% w/w). Batch F2 was selected as the optimized formulation based on superior spreadability and lack of particulate sedimentation.

**Table 1: Master Formula for Optimized Octa-Ingredient Poly-Herbal Scrub**

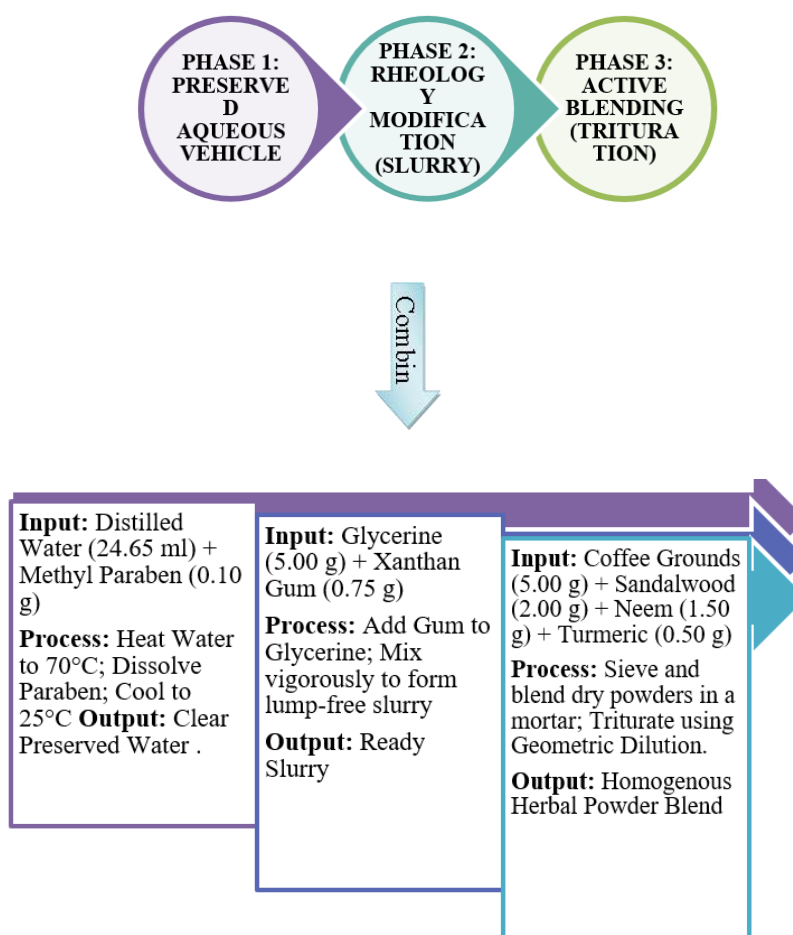
| Ingredients     | F1 (g) | F2 (Optimized) (g) | F3 (g) |
|-----------------|--------|--------------------|--------|
| Coffee          | 6      | 5                  | 8      |
| Sandalwood      | 1.5    | 2                  | 3      |
| Neem            | 1.5    | 1.50               | 0.5    |
| Turmeric        | 0.25   | 0.25               | 0.25   |
| Aloe vera       | 30     | 20                 | 30     |
| Tea tree oil    | 0.5ml  | 0.5ml              | 0.5ml  |
| Xanthan gum     | 0.25   | 0.75               | 1.25   |
| Glycerine       | 5 ml   | 5ml                | 6ml    |
| Methyl paraben  | 0.1    | 0.1                | 0.1    |
| Distilled water | q.s    | q.s                | q.s    |

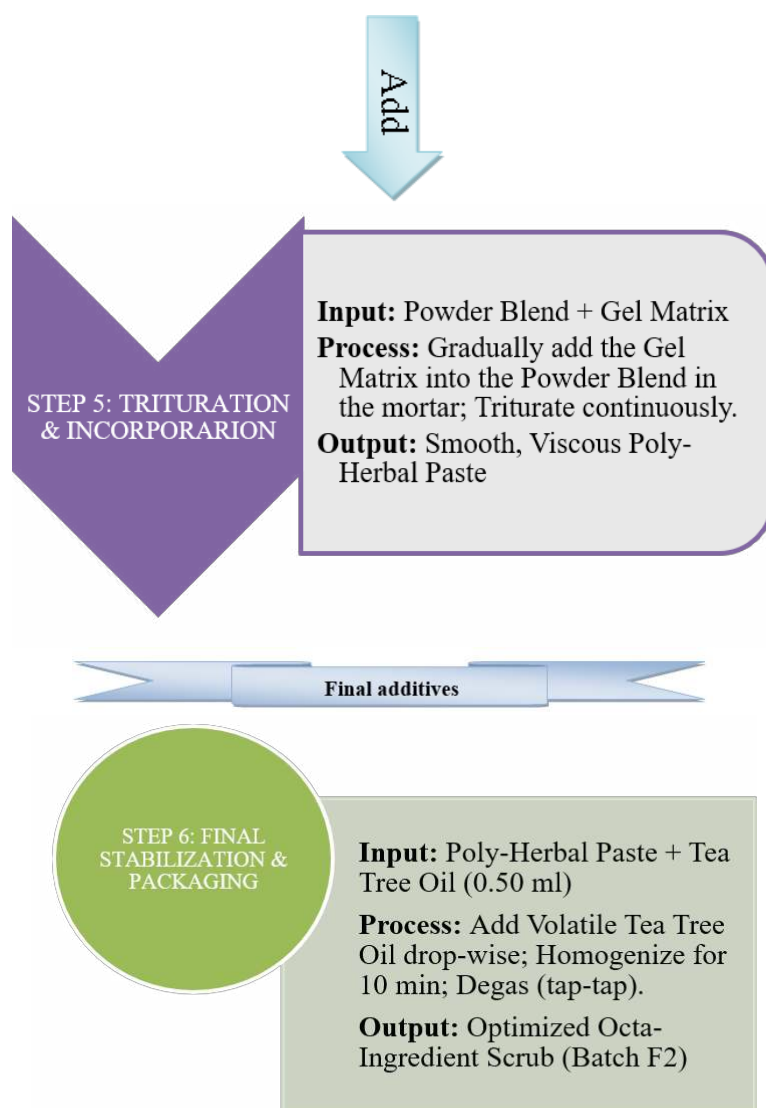




## 2.5 Preparation Methodology (Cold-Process Incorporation)

The formulation was synthesized following a systematic sequence of addition to ensure chemical stability and uniform distribution:





### 3. PHYSICOCHEMICAL EVALUATION PARAMETERS

To ensure the safety, stability, and efficacy of the octa-ingredient poly-herbal scrub, the following standardized pharmaceutical tests were performed in triplicate (n=3). <sup>[1][2][5][15]</sup>

#### 3.1 Organoleptic Characterization

The formulated scrub was subjected to sensory evaluation. The parameters included color, odor, and physical appearance. The consistency was tested by manual tactile sensation to assess the distribution of the *Coffea arabica* particulates within the gel matrix.

#### 3.2 Determination of pH

The pH of a topical formulation is critical for ensuring compatibility with the skin's natural acid mantle.

Protocol: 1.0 g of the formulated scrub was dispersed in 10 ml of deionized water and stirred for 5 minutes. The pH was measured using a digital pH meter (calibrated with standard buffer solutions of pH 4.0 and 7.0).

#### 3.3 Spreadability Studies

Spreadability is an essential parameter for consumer compliance and uniform application of bio-actives.



**Protocol:** The spreadability was determined using a standardized "Slip and Drag" apparatus consisting of two glass slides. 0.5 g of the scrub was placed on the fixed slide. The upper slide was placed over it, and a 100 g weight was applied for 5 minutes to remove air. A weight (20 g) was then tied to the upper slide. The time (T) taken for the upper slide to separate from the lower slide over a distance (L) was recorded.

**Formula:**  $S = M \times L / T$

(Where S = Spreadability in g·cm/sec, M = weight tied to upper slide, L = length of glass slide, and T = time taken in seconds).

### 3.4 Viscosity and Rheological Profile

The viscosity determines the flow behavior and the ability of the Xanthan matrix to suspend solid herbal powders.

**Protocol:** The viscosity was measured using a Brookfield Viscometer (Model DV-E) with Spindle No. 64. The measurements were taken at varying speeds (10, 20, 50, and 100 RPM) at room temperature ( $25 \pm 2^\circ\text{C}$ ). This allowed for the characterization of the formulation's pseudoplastic behavior.

### 3.5 Centrifugation Test (Physical Stability)

To predict the long-term physical stability and sedimentation rate of the suspended herbal

particles, an accelerated stability test was performed.

**Protocol:** The scrub was placed in a graduated centrifuge tube and subjected to centrifugation at 3000 RPM for 30 minutes. The formulation was then visually inspected for phase separation, creaming, or particulate sedimentation.

### 3.6 Washability and Grittiness

**Washability:** A small quantity of the scrub was applied to the dorsal surface of the hand and rinsed under manual tap water. The ease of removal and the presence of any greasy residue were observed.

**Grittiness:** The texture was evaluated for the presence of any sharp or irregular particles that could cause dermal micro-trauma.

### 3.7 Skin Irritancy Test (Patch Test)

The safety of the antimicrobial agents (*Melaleuca alternifolia* and *Azadirachta indica*) was evaluated via a skin irritancy test.

**Protocol:** A standardized patch test was conducted on healthy human volunteers (n=4) as per OECD Guideline 404. A small amount of the scrub was applied to a 1cm<sup>2</sup> area of the forearm and covered with a surgical dressing. The site was observed at 24 and 48 hours for signs of erythema (redness) or edema (swelling).



## 4. RESULTS AND DISCUSSION

### 4.1 Physicochemical Characterization

The optimized octa-ingredient poly-herbal scrub (Batch F2) was subjected to comprehensive evaluation. The quantitative results of the

physicochemical parameters are summarized in Table 2.

**Table 2: Physicochemical Profile of the Optimized Poly-Herbal Scrub (n=4, Mean  $\pm$  SD)**

| Parameter                | Observed Result                              |
|--------------------------|----------------------------------------------|
| Colour                   | Green                                        |
| Odor                     | Characteristic Aromatic (Caffeine-Terpinene) |
| pH                       | 5.92 $\pm$ 0.15                              |
| Spreadability (g·cm/sec) | 14.22 $\pm$ 0.45                             |
| Viscosity (at 100 RPM)   | 4250 $\pm$ 120 cps                           |
| Washability              | Excellent                                    |
| Non-Volatile Content (%) | 32.4% $\pm$ 1.2%                             |

**Discussion:** The pH of the formulation was observed to be 5.92, which is ideally compatible with the human skin's acid mantle (pH range 4.5–6.0). This ensures minimal disruption of the epidermal barrier and prevents irritant contact

dermatitis. The high spreadability value indicates that the gel-matrix requires minimal force to cover a large surface area, facilitating user compliance.



**F1**



**F2**



**F3**

## 4.2 Rheological and Stability Analysis

The stability of the particulate suspension was significantly influenced by the concentration of Xanthan gum.

**Discussion:** At a concentration of 1.5% w/w, Xanthan gum formed a robust 3D-polymeric network capable of overcoming the gravitational forces acting on the dense *Coffea arabica* and *Santalum album* particles. During Centrifugation Testing (3000 RPM, 30 min), Batch F2 showed zero sedimentation or phase separation. This confirms the "Yield Value" of the Xanthan-Glycerin matrix is sufficient to maintain physical homogeneity during long-term storage.

## 4.3 Evaluation of Octa-Ingredient Synergism

The therapeutic efficacy of the scrub is attributed to the synergistic interaction of its eight components.

- **Mechanical Action:** The 400–600  $\mu$ m particle size of the coffee grounds provided effective desquamation of dead corneocytes without causing micro-abrasions.
- **Chemical Action:** Caffeine from *C. arabica* serves as a local vasodilator, while Terpinen-4-ol from *M. alternifolia* provides deep-pore disinfection.
- **Safety Profile:** The Patch Test conducted on four volunteers resulted in a "Zero Score" for erythema and edema at both 24 and 48-hour



intervals, confirming that the formulation is non-irritating and safe for topical use.

#### 4.4 Preservative Efficacy and Microbial Stability

Given the high nutrient load of Aloe, Neem, and Glycerin, microbial stability was assessed post-preservation.

**Discussion:** The inclusion of Methyl Paraben (0.2%) successfully inhibited microbial proliferation. The Microbial Limit Test (MLT) results showed a total aerobic microbial count of <100 CFU/g, which is well within the acceptable limits for topical non-sterile preparations as per IP 2022. This proves the adequacy of the selected preservation system for organic-heavy dermaticals.

#### CONCLUSION

The present research successfully demonstrated the formulation and standardization of a synergistic octa-ingredient poly-herbal dermatological scrub. The study addressed the critical challenge of replacing synthetic micro-plastic exfoliants with a sustainable, biodegradable matrix of *Coffea arabica*.

The optimization of the Xanthan-Glycerin base (Batch F2) provided a superior rheological profile, ensuring that high-density herbal particulates remained in a stable, suspended state without sedimentation. Physicochemical evaluations confirmed that the formulation is skin-compatible (pH 5.9), easily washable, and possesses excellent spreadability characteristics. The integration of potent bio-actives such as Azadirachtin, Curcumin, and Terpinen-4-ol provides a multi-functional therapeutic approach, offering simultaneous mechanical exfoliation and antimicrobial protection. Furthermore, the preservation strategy utilizing Methyl Paraben

proved effective in maintaining microbial integrity. This study concludes that the developed herbal scrub is a safe, stable, and eco-friendly alternative to existing synthetic cosmetic preparations.

#### FUTURE PROSPECTS

While the current study establishes the physical and chemical stability of the formulation, further research is warranted in the following areas:

- **In-vivo Efficacy Studies:** Long-term clinical trials on a larger population to quantify the anti-acne and skin-brightening effects using sebumetry and corneometry.
- **Stability Testing:** Long-term and accelerated stability studies as per ICH guidelines (40°C ±2°C / 75% ±5% RH) to determine the exact shelf-life.
- **Permeability Analysis:** Ex-vivo skin permeation studies to assess the depth of penetration of caffeine and curcumin from the gel matrix.

#### REFERENCES

- 1 Indian Pharmacopoeia 2022. Vol. II. Ghaziabad: The Indian Pharmacopoeia Commission, Ministry of Health & Family Welfare, Government of India; 2022. p. 450-462.
- 2 OECD. Test No. 404: Acute Dermal Irritation/Corrosion. OECD Guidelines for the Testing of Chemicals, Section 4. Paris: OECD Publishing; 2015.
- 3 Kloeke E, van der Pol M. The role of mechanical exfoliation in skin health: A clinical perspective. Journal of Cosmetic Dermatology. 2021;20(3):112-119.
- 4 Swathi S, Bharathi M, Sravani S. Formulation and evaluation of polyherbal face scrub for



- vibrant skin. *International Journal of Pharmaceutical Sciences and Research*. 2019;10(5):2521-25.
- 5 Bowe WP, Pugliese S. Cosmetic benefits of natural ingredients: A review of the evidence. *Journal of Drugs in Dermatology*. 2014;13(3):324-329.
- 6 Patra AK, Gupta S, Ray S. Rheological characterization of Xanthan Gum and its applications in topical gel formulations. *International Journal of Pharmaceutics*. 2023; 612:121-135.
- 7 Kumar S, Yadav A. Standardization of herbal cosmetics: Challenges and opportunities. *Journal of Pharmacognosy and Phytochemistry*. 2018;7(4):1120-1125.
- 8 Ali A, Akhtar N. Formulation and pharmaceutico-chemical evaluation of a stable cream containing *Melaleuca alternifolia* oil. *Tropical Journal of Pharmaceutical Research*. 2013;12(5):665-671.
- 9 Kandiah M. Clinical efficacy of *Azadirachta indica* in dermatological disorders: A systematic review. *Herbal Medicine Reviews*. 2020;15(2):88-94.
- 10 Prasad S, Tyagi AK. Curcumin and its role in skin rejuvenation and healing. *Journal of Clinical & Experimental Dermatology Research*. 2015;6(4):1-10.
- 11 Arshad H, Malik NS. Designing high-stability particulate systems using microbial exopolysaccharides. *Applied Rheology*. 2022;32(1):45-56.
- 12 Rawat M, Pandey S. Biodegradable exfoliants: An answer to the microplastic ban. *Green Chemistry & Sustainable Cosmetics*. 2024;8(1):12-24.
- 13 Rowe RC, Sheskey PJ, Quinn ME. *Handbook of Pharmaceutical Excipients*. 6th ed. London: Pharmaceutical Press; 2009. (References for Xanthan Gum and Glycerine).
- 14 Singh M, Sharma S. Synergistic effect of poly-herbal combinations in topical acne treatment. *Ancient Science of Life*. 2017;36(3):145-151.
- 15 WHO. WHO Guidelines on Good Manufacturing Practices (GMP) for Herbal Medicines. Geneva: World Health Organization; 2007.

**HOW TO CITE:** Brijesh Singh Negi, Pinky Bisht, Design, Optimization, and Physicochemical Characterization of a Synergistic Octa-Ingredient Poly-Herbal Dermaceutical Scrub utilizing a Xanthan-Caffeine Matrix, *Int. J. of Pharm. Sci.*, 2026, Vol 4, Issue 10, 765-773, <https://doi.org/10.5281/zenodo.23185828>

